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Impact of the Design of Neonatal Intensive Care Units on Neonates, Staff, and Families

A Systematic Literature Review

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ABSTRACT

Newborn intensive care is for critically ill newborns requiring constant and continuous care and supervision. The survival rates of critically ill infants and hospitalization in neonatal intensive care units (NICUs) have improved over the past 2 decades because of technological advances in neonatology. The design of NICUs may also have implications for the health of babies, parents, and staff. It is important therefore to articulate the design features of NICU that are associated with improved outcomes. The aim of this study was to explore the main features of the NICU design and to determine the advantages and limitations of the designs in terms of outcomes for babies, parents, and staff, predominately nurses. A systematic review of English-language, peer-reviewed articles was conducted for a period of 10 years, up to January 2011. Four online library databases and a number of relevant professional Web sites were searched using key words. There were 2 main designs of NICUs: open bay and single-family room. The open-bay environment develops communication and interaction with medical staff and nurses and has the ability to monitor multiple infants simultaneously. The single-family rooms were deemed superior for patient care and parent satisfaction. Key factors associated with improved outcomes included increased privacy, increased parental involvement in patient care, assistance with infection control, noise control, improved sleep, decreased length of hospital stay, and reduced rehospitalization. The design of NICUs has implications for babies, parents, and staff. An understanding of the positive design features needs to be considered by health service planners, managers, and those who design such specialized units.

Key Words: healthcare design, infant, NICU, open bay, parents, preterm, single-family room, staff

Preterm infants, that is, those with less than 37 completed weeks of gestation, account for about 7% of the 280 000 births in Australia.[1] In the United States in 2008, preterm births account for 12.3% of all births.[2] Many of the preterm babies admit to a neonatal intensive care unit (NICU) to provide care and ongoing support. Neonatal intensive care units are highly technological spaces that incur considerable costs due to the critical nature of the care provided. In recent years, many new units have been built in Australia and other "similar" countries and there is ongoing refurbishment of older units. Since the emergence of Neonatal Developmental Supportive Care in the early 1980s, many NICUs have had to reconsider their physical layout in order to support this model of care.[3] It is therefore essential that the design of NICUs be considered in terms of the contribution to outcomes for babies and experiences for parents and staff.

In the past 2 decades, there has been an increasing interest on the design features of acute care hospital

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facilities including NICUs. A positive, physical healthcare environment is said to be a healing environment and has been shown to have beneficial effects on the well-being of patients, the caregiving process, and family comfort.[4,5] Many studies highlight the potential effect of physical healthcare environments on the health outcomes and well-being of patients in healthcare settings.[4] The physical environment has been shown to play a significant role in healing and contributes to clinical, operational, and social dimensions in healing.[6]

In light of these changes, the design of acute healthcare environments needs to be considered. One acute care area that has received some attention is the NICU. Both Walsh et al[7] and Carlson et al[8] have reviewed the history of NICU design. Original designs of NICUs had multiple bassinets, organized in an open space without fixed partitions or walls between them. During the 1970s and 1980s, the significance of parent involvement in patient care was established in the field.[9] This was a change in the philosophy of care, and a gradual evolution in design took place from open-bay wards to pods, pin wheels, and divided bed spaces open on one side to finally completely private patient rooms for neonates and their families. Single-family rooms were established as they were seen as being better for babies,[10] as they enhance privacy,[8,11,12] facilitate parental participation in care,[13] control infection,[7,10,14] control noise[7,14–16], and reduce length of hospitalization.[11,13] Although single-family rooms are growing in popularity in many hospitals, there are concerns about the isolation of neonates and their parents away from other families and the potential lack of social support that single rooms may inadvertently cause. Anecdotally, staff in some NICUs with a single-room design report feeling isolated from their colleagues and experience an increased amount of walking, as the NICU is usually larger to accommodate single rooms. Staff perceive a decreased ability to monitor multiple infants in separate single rooms and have difficulty providing support to each other while monitoring one's own patients.

With these issues in mind, we undertook a systematic literature review to explore these issues. The aim of the review was to describe the main features of NICU design and determine the advantages and limitations of the design in terms of outcomes for babies, parents, and staff.

METHODS

A systematic review of English-language, peer-reviewed articles was conducted. The PICO (Population, Intervention, Comparison, and Outcome) principles were used to formulate clinical questions that guided the search strategy. The questions were as follows: What are the benefits associated with different designs (O) for babies who are admitted to an NICU (P) comparing different design features, for example, open-bay (I) versus single-family room (C). Essentially, the positive and negative design features of the NICU were explored.

We searched through 4 main online databases for health, that is, CINAHL (Cumulative Index to Nursing and Allied Health), Ovid MEDLINE, ScienceDirect, and the Cochrane Library. Key words used were "hospital design," "single (patient) room," "open ward," "healing environment," "built, environment," "developmental care," "health outcomes," "neonatal intensive care unit," "unit design," "nurse," "physician," "family," and "healthcare."

The reference lists of included articles were checked to determine other articles for inclusion. The inclusion criteria were all studies written in English that evaluated NICU design features and impacts on infants, staff, and families; involved a comparison group (randomized control trials [RCTs], cohort studies, and before and after studies); and published from January 2000 to January 2011. Studies that did not report specific design features of the NICU and their impact on outcome measures were excluded. Figure 1 provides an explanation of the search strategy and the number of articles located at each point.

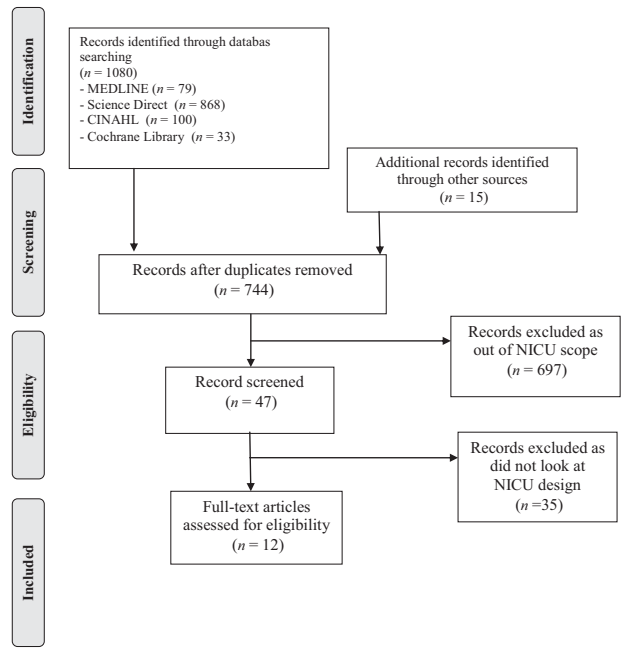

Figure 1. Flowchart explaining the search strategy and final articles included. Abbreviations: CINAHL, Cumulative Index to Nursing and Allied Health; NICU, neonatal intensive care unit.

Types of outcome measures

A number of outcome measures were examined in the study on the basis of the work of Ulrich et al,[5] who conducted a comprehensive literature review that linked characteristics of the physical environment of hospitals to staff stress, quality of care delivered, and patient outcomes. The main outcome measures examined are described in Table 1.

Data extraction

After the search, studies reporting physical interventions were grouped by 4 major categories of design intervention to determine the advantages and limitations of the design in terms of outcomes for babies, parents, and staff. A narrative summary was undertaken to report the findings. A meta-analysis was not undertaken because of insufficient number of studies and the lack of numerical data.

FINDINGS

The initial search retrieved 1080 studies. After excluding the duplicate articles, the titles of 744 articles were read and 697 were excluded, as they did not relate to NICU facilities. Of these 47 potentially relevant articles, we excluded 35 studies, as they did not study the impact of NICU design on infants, staff, and families (see the Figure).

Twelve articles met the inclusion criteria. These included 1 RCT, 4 prospective comparative studies, 3 before and after studies, 3 cross-sectional or descriptive studies, and 1 qualitative study. Twelve studies addressed the 5 outcome categories, that is, infection control; length of stay; noise; workload and communication; and privacy and comfort. Some studies addressed more than 1 outcome category (see Table 2).

Table 1. Outcomes measures examined in the literature review

Main outcomes
Staff stress and effectiveness in delivering care
Patient safety
Health outcomes
Overall healthcare quality
Other outcomes
Infection control
Length of stay and rehospitalization
Noise on neonates
Workload and communication between staff
Privacy and comfort for parents

NICU ENVIRONMENT AND EFFECT ON INFANTS

Patient medical progress including infection control

Three cohort studies[7,10,14] and 1 RCT[13] addressed the link between the built environment, infection, and patient progress in NICU. Domanico et al[14] undertook a study comparing infants in single rooms with those in an open-bay area. Apnea-prone infants who were 36 weeks or less of postmenstrual age had a 57% reduction in apnea events when in single-family rooms compared with those in open-bay areas. Furthermore, mechanical ventilation, positive air pressure, and apnea events were reduced in single-family rooms.[14]

Different factors were identified or implicated as contributing to improved health outcomes in single-family rooms. Ortendstrand et al[13] undertook a RCT of 2 contrasting unit designs, that is, standard care or open bays versus single-family rooms. This trial showed a lower risk of moderate to severe bronchopulmonary dysplasia in the group randomized to the single-family rooms compared with open bays. Parents of infants in the single rooms were able to stay 24 hours a day, whereas parents whose infants were in the open bays had limited opportunities to stay overnight. This extended parental access might have contributed to improved outcomes for the babies.

Outcomes for patients cared for in single rooms revealed a consistent pattern of reduced infection rates compared with those cared for in shared rooms. One study conducted in the United States showed a reduction in catheter-associated bloodstream infections from 10.1 per 1000 device-days to 3.3 per 1000 device-days over a 9-month period after babies were moved from an open-bay environment to a single-family room.[7] In the studies by Walsh et al[7] and Cone et al,[10] staff perceived an improvement in hand washing in single-family rooms compared with open bays due to installing sinks or hand-cleaner dispensers in each patient room.

Length of stay and rehospitalization

At least 3 studies using a single-family-room approach showed decreased NICU length of stay[11,13] and lower rehospitalization rates compared with open bays.[17] One before and after study undertaken[11] evaluated the lengths of stay in single-family rooms and in open bays. More than one-half of infants (59%) cared for in an open bay had a length of stay of less than 14 days. Once the NICU was moved to a new environment with single-family rooms, 76% of infants had a length of stay of less than 14 days. It is possible that single rooms facilitate greater parent involvement in care and enable practices such as breastfeeding and skin-to-skin care more readily

Table 2. **Included studies by outcome and author, year, country, and study design**

Trial (author and date)	Country	Design
Infection control ($n = 3$)		
Cone et al[10]	United States	Cross-sectional survey
Walsh et al[7]	United States	Descriptive cohort (quantitative)
Domanico et al[14]	United States	Prospective comparative
Length of stay ($n = 3$)		
Carter et al[11]	United States	Descriptive cohort (quantitative)
Erdeve et al[17]	Turkey	Prospective comparative
Ortenstrand et al[13]	Sweden	Randomized controlled trial
Noise ($n = 3$)		
Walsh et al[7,a]	United States	Descriptive cohort (quantitative)
Domanico et al[14,a]	United States	Prospective comparative
Krueger et al[16]	United States	Before and after (quantitative)
Chen et al[15]	Taiwan	Prospective comparative
Workload and communication ($n = 5$)		
Cone et al[10,a]	United States	Cross-sectional survey
Walsh et al[7,a]	United States	Descriptive cohort (quantitative)
Shepley et al[18]	United States	Prospective comparative
Smith et al[19]	United States	Before and after (quantitative)
Carlson et al[8]	United States	Before and after (qualitative)
Privacy and comfort ($n = 4$)		
Carter et al[11,a]	United States	Descriptive cohort (quantitative)
Beck et al[12]	Denmark	Qualitative
Carlson et al[8,a]	United States	Before and after (qualitative)

[a]These studies addressed more than 1 outcome category and so are included more than once in the table.

than open bays. The resulting enhanced parental participation might be a factor in the reduced length of stay.

There was only 1 RCT included in this review. Ortenstrand et al[13] randomized 366 infants born before 37 weeks of gestation in 2 NICUs. The 2 groups were standard care, which was provided in open bays, compared with family care, that is, single rooms with unlimited parent presence. The total length of hospital stay for premature infants born before 37 weeks of gestation was 5.3 days shorter in the family care group (single room) than in the standard care group.[13]

The availability of individual rooms seemed to promote parental interaction with the baby and led to decreased rates of rehospitalization.[18] One prospective cohort study was conducted with 2 groups of mothers in 2 different hospitals. Mothers who stayed with their preterm infants in single bay areas (group I) were compared with mothers who did not stay overnight with their preterm infants while being cared for in open-bay areas (group II). The findings demonstrated that infant rehospitalization rates were significantly lower (12.9% vs 34.5%) when infants were cared for in the single-family rooms. Erdeve et al[17] also noted that the major cause of rehospitalization for infants whose mothers were not staying with them in hospital while being cared for was feeding difficulties. Although family-centered care can be successfully implemented in open-bay wards, single-family rooms provide more opportunity for rooming-in prior to discharge.[18] These 3 studies highlight that the increased involvement of parents in the single rooms may influence outcomes for the babies.

Noise

Four studies focused on noise in the NICU and examined environmental interventions in reducing noise and its effect on outcomes. Noise was found to be not only detrimental to infants but has also been identified as a stressor for staff and families.[7,15] Despite the broad impact of noise, no studies examined the effect specifically on staff. The following studies focused on the impact on the neonates.

Noise in NICU is a highly negative environmental characteristic that increases neonates' heart and respiration rates, contributes to sleep disturbance and hearing impairment, decreases oxygen saturation[15,16] and has a negative impact on nervous system development.[14]

Ambient noise levels in open-bay settings were found to be higher than in single-family rooms.[14,15] Using a cohort study design, Chen et al[15] measured noise levels continuously for 24 hours a day in 2 separate NICU designs. Their study indicated that noise levels in the open space were higher than that in an enclosed space, that is, in a single room. Another cohort study[14] found the most important sources of noise

in open-bay area came from staff and visitor activities, and it was loudest in areas close to the NICU entry or the nurses' desk during visiting hours and shift change.

A before and after study of sound levels by Krueger et al[16]found that sound levels after reconstruction into a single room were lower than that in an open plan ward. Although the study demonstrated the positive impact that single rooms can have on sound levels, additional interventions may be required to reduce the current standard noise level in NICUs. Environmental interventions that have been found to be effective in mitigating noise include providing single rooms rather than open bays, continuous monitoring of sound levels,[15] installing soft vinyl floors, installing sound-absorbing materials in the ceiling, and making an ongoing effort to reduce noise.[7,16] Single rooms, in particular, reduce the sound level by having fewer people and machines in a concentrated area. They also provide families with the feeling of enhanced privacy.[15]

NICU ENVIRONMENT AND THE EFFECT ON STAFF

Workload and communication

The NICU environment can be highly stressful for healthcare staff, suggesting that, to reduce stress, the facility layout must support their activities. Five studies examined the impact of NICU design on staff. In particular, 4 studies examined the walking required by staff in the different designs. All these studies[7,8,10,19] showed that the layout of the NICU (single room vs open bay) impacted on the time required to travel from room to room and the perceptions of care by the nurses. Nurses working in open-bay NICUs walked less and were able to monitor infants visually from the nursing station,[7,19] whereas nurses providing care in single-family rooms found that it was unsettling not to be aware of the progress and status of other patients.[8] Walsh et al,[7] in a before and after study of 127 nurses' perceptions after a move into an NICU with single rooms, reported that the majority of nurses (70%) believed that having single rooms was physically harder and stated that the additional walking required to cover the unit added to their workload. Regardless of patient acuity, there was a consensus that patient assignment in single rooms should be limited to no more than 2 per nurse to account for the increased distances and feelings of isolation.[7,10]

Four studies examined the effectiveness of communication in NICU settings.[7,10,19] In a study of 21 staff, 1 year after moving into a single-room design, the single-room layout was perceived to separate staff from one another and reduced opportunities for talking, support, and ongoing education.[19] Concerns about decreased communication and staff interaction were mostly related to the single-room design compared with open-bay designs. A number of strategies were proposed to address these issues including ensuring the nurses' station and medical work areas are adjacent to the patient rooms[10] and providing adequate or sufficient staffing.[7]

Privacy and comfort

Three studies have linked the design of the NICU to family comfort.[8,11,12] A study conducted by Carlson et al[8] in the United States indicated that within 6 months after moving into a single-family room design, parents reported improved privacy compared with the previous open-bay layout. Parents reported feeling like visitors in the open-bay design. They felt a lack of privacy to express their joy and sorrow. However, the parents felt like a family unit in a room. The experience of comfort and being shielded from the other parents' emotional expression and from the noise simulated feelings of privacy.[12] Another cohort study by Carter et al,[11] again in the United States, showed that privacy in a single-room design may have been affected by 2 factors: the greater physical space and unlimited parental visitation.

DISCUSSION

The design of the NICU does impact on outcomes for patients, families, and staff, although only a limited number of studies were found that specifically addressed this issue. Single-family rooms are associated with shorter length of stay, increased privacy and opportunities for parental interaction, and fewer patient infections than those associated with open-bay wards. Parents preferred the intimacy of a single-family room, and the noise levels were also decreased. Although staff valued the reduced noise in the single-family rooms, this was balanced with concerns about increased distances between infants and the diminished opportunities for staff interaction.

When considering NICU design and unit configuration, it is important to remember that families and staff have different needs. The family needs include an emphasis on privacy and individualized care, whereas the staff needs often emphasize efficiency and visibility. A number of studies on design configuration in the NICU unit examined workload and communication. The majority of these studies showed that communication happened naturally and constantly among nurses and physicians in an open-bay ward whereas in the single-family room design, the levels of constant communication and patient monitoring were often reduced.

The nurses in the single-room NICU design expressed concerns that the decreased visibility of infants would affect their workload and infant outcomes. The

nursing staff believed that single rooms were physically harder because of the time spent walking, which increased as the overall footprint of the unit increased. To remedy this problem, clustering patients and having centralized supply areas are suggested.[10] Ulrich et al[5] found that a design that placed patient rooms close to one another (in a radial or circular design) and decentralized nurses' stations could reduce staff walking and fatigue, increase patient care time, and improve staff communication.

The systematic review of the design and health literature by Ulrich et al[5] demonstrated that single rooms allow more privacy for parent-infant interactions and protected them from environmental noise. Environmental noise is a significant cause of stress in healthcare facilities, and strategies to reduce noise should be implemented. Noise levels can be substantially reduced by implementing environmental interventions such as the installation of sound-absorbing materials in ceilings and the removal of noise sources. Establishing a quiet environment in NICU is essential, in particular to improve the infant's sleep, control heart and respiration rates, and enable families to have a peaceful time with their infants.

Although a small number of studies demonstrated benefits of comparing open-bay versus single-family rooms, there are a number of limitations that need to be considered. Overall, there were few studies undertaken in this area. Only 12 studies directly examining design in NICUs were identified out of more than 1000 initially identified. Only one study was a RCT, and few were comparative studies. The level of evidence in the available studies was not high—many were before and after studies, which have the potential for significant bias. Although RCTs are difficult in this area, research designs that reduce bias need to be undertaken to strengthen the evidence base in this area.

Given the considerable amount of resources spent on building, refurbishing older units, and caring for infants in these units, very little research has been undertaken on the actual design of the NICU, which limits this review. Most of the studies were conducted in the United States, and although their findings are probably generalizable to other developed nations, more research that addresses specific contexts and settings in other countries is required to increase the evidence base.

CONCLUSION

The findings of this review collectively link a range of aspects of the physical environment of NICU to well-being of patients, family comfort, and the caregiving process. This article recommends that consideration of the design and environment is important for the health and well-being of neonates in the NICU, including noise control, infection control, and privacy. Provision of single rooms per se is a more controllable environment for preterm infants, and it improves health progression compared with open-bay units. Parental involvement in single rooms not only minimized hospitalization and rehospitalization rates but also enabled parents to feel more comfort and privacy. Potential limitations of the single-family-room design are that they increased staff workload, reduced the visibility of infants to staff, and reduced communication among staff. These would be mitigated by improved design layout and decentralized nursing stations.

Further research is needed on those aspects of single-room design that decrease staff communication and patient visibility. This literature review provides information to assist a range of disciplines including architects, designers, and health service managers who are involved in NICU design. An interdisciplinary sharing of knowledge between stakeholders such as clinicians, managers, and architects could ensure that research evidence was applied in the design of NICUs. Research in ways to improve the environment for babies, parents, and staff is needed, including developing and testing innovative designs that reduce the distance that staff need to walk while ensuring privacy and intimacy for parents and examining the most effective ways to ensure families have social support, perhaps from other families, in an NICU that has single rooms. Exploring the best way to improve staff to staff communication is also needed whether this be through having central workspaces, using interactive media such as video or instant messages systems, or changing management systems to reduce the size of the functional unit. Future research also needs to examine the impact of specific issues, such as noise, on the staff and families. This needs to explore which aspects of noise create stress and anxiety for families and staff and how this can be mitigated. For example, a better understanding of whether the stress-creating noise is from alarms that may also highlight health concerns with the baby or whether background and staff-produced noise itself create stress. Such future studies could have significant impacts on the design of NICUs and on future cost-effective models of care in these settings.

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